# COMPARING MANUALLY MEASURED ANTHROPOMETRICAL POINTS OF HUMAN FACES WITH FULLY COMPUTERIZED ONES

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**Abstract:** This paper deals with the analytical-statistical method of one of the most used biometrics, the face recognition. The research project shows changes in face of ten different women, and emotional changes of one woman. The distances' changes of the chosen anthropological points were measured to obtain better understanding of programming requirements for better reliability of those systems. As the measurements were done entirely manually and processed by the spreadsheet program, it was also compared to some of the values obtained earlier by fully computerized method. To acquire comparable data, the same methodology of experimental calculation was used.

**Keywords:** analytical-statistical method, face recognition, distance measurement, anthropological points, relative coefficients.

## 1. INTRODUCTION

Face recognition is one of the most used technologies in todays' security applications. Reliability of these systems is really high, although some errors may occur. Such error cause, in the better case the discomfort of the user who has to log repeatedly, in the worst case the intruder is allowed to the system or to the protected building. To avoid situations like this, neural networks are used mainly in combination with standard methods like statistically oriented methods (e.g. subspace method) and knowledge methods (e.g. methods based on symmetry). Another solution may be a multi-modal biometrics, for example the combination of gait and face recognition, fingerprint and face recognition, or face and fingerprint and iris recognition systems.

The origin of the face recognition is in the anthropometry by Alphonse Bertillon as a developer of this criminalistic field. As classical portrait identification, the shape, fullness and colour are described together with supplemental characteristics like wrinkles and their length and depth, dimple in the chin, faces, cosmetic defects, scarfs, etc. [1]. This practically laid the bases for analytical-statistical method of personal identification based on photographical portrait, which deals with the calculation of distances of landmarks (anthropometrical points) and their space transformations.

The basic 12 points, which are enough for recognition, are following [1] and [2]: inner and outer tail of eyes (points 4, 5, 6, 7), outer horizontal points of lips (points 1, 2), *glabella* (point 8), lower edge of nose's tip (point 3), ear cartilage – *tragus* (points 9, 10), transition of ear-lobe to the face – *cauda belicis* (points 11, 12). These points are also shown in Fig. 3. Although these 12 points are enough, we can add extra ones if they are better adapted to the images and are clearly visible in both photographs compared. However, we must bear in mind that some, especially easily modified features should be omitted as suitable points (like hair features or the hairline). In [2] the author wrote that height and width dimensions, not defined by fixed points and requiring judgment by the observer are the most unreliable and unpredictable ones. On the other hand, features like face shape have higher rates of interobserver agreement, and pronounced ear projection is said to be the best discriminators.
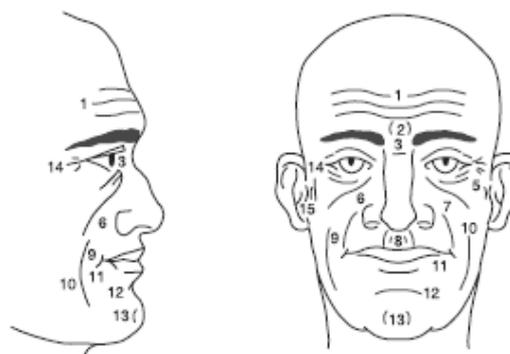


**Figure 1** – Wrinkle patterns of the face [2]
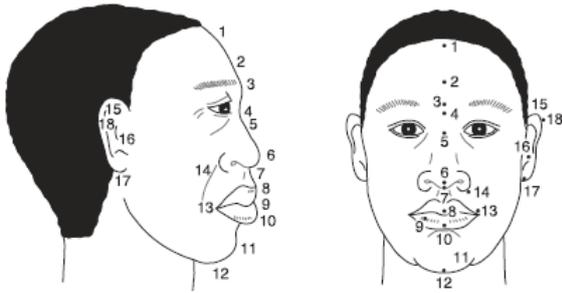
**Figure 2** – Anatomical landmarks of the face [2]

However this method (also called photoanthropometry [1], [2]) is not separately very sufficient and thus must be combined with another method to be adaptable to various facial features.

The nowadays methodology using calculation of distances is the method based on geometrical shapes and identification of anthropometric points, which has only the bases of the analytical-statistical method in common. The resolution of processed image for the use in police-court (forensic) applications is set to be standardly 500 dpi (e.g. used by FBI also for fingerprint recognition [1]). Generally, the higher the resolution of the processed image, the more precise the identification process is [2].

However, the methodologies used today are mainly three-dimensional or two-dimensional combining various available methods, which lower the possibility of low identification accuracy and potentiality to mistaken identity due to the low resolution of the processed images (e.g. using images from industrial cameras at the petrol station), which occurred in the photoanthropometry.

Apart from the resolution of the image, it is also necessary to choose the correct anthropometrical points on the human face. Basically, 12 points (Fig. 3) are enough for correct recognition of the person by the analytical-statistical method. These 12 points can give 66 abscissae describing the space and linear identity of the human face [1], whose lengths are calculated and compared to other ones.
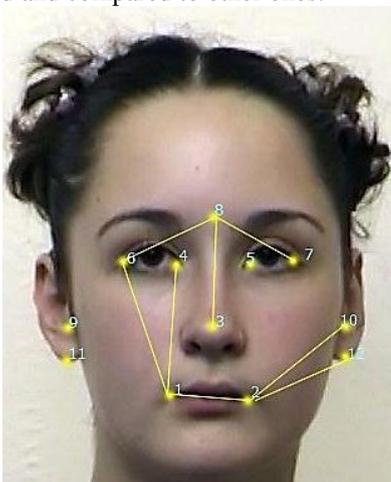


**Figure 3** – 12 basic anthropometric points and example of their connection [1]

## 2. METHODS

### 2.1. Software

The basic measurements were done by the help of the Adobe Photoshop CS 5 ver. 10.0 (64 bit version), where the images obtained from the University of Stirling (UK) could be easily measured manually in pixels or centimetres. The manual measurement was chosen to avoid errors made by the software and to compare coefficients calculated in previous research [1] and in this research. As the whole process of data acquisition is very demanding, ten faces were chosen to simplify the procedure.

The data were collected, calculated and evaluated in the MS Excel 2010. The in-depth control of data was done by the STATISTICA ver. 7.0 software.

### 2.2. Images

The proportions of images were 720 × 576 pixels (≈ 25.4 cm × 20.32 cm), the resolution was 72 dpi. The project was at first done for 12 selected anthropometrical points (Fig. 3) for better comparison with fully computerized method, though 17 and finally 28 points were chosen for further data analyses. For this 12 points, the distance between each pair of points, respectively the lengths of chosen abscissae were measured three times. As the pupils or eyebrows were not visible in some cases, or the boundaries were not sharp enough, their length were not derived. For the selected two sets of images, the angles between chosen anthropometric points were measured to see the changes against the direct look/various emotions of the model(s). The distances were measured in pixels, angles were read in degrees.

As in all analyses, the points used for indices must be clearly visible and defined if they are not on standard sites (e.g. 28 chosen points).



**Figure 4** – Selected 11 faces in the first set

An important consideration for this approach is not to limit the analysis to pre-set or traditional points. The quality and angulation of the image may dictate the use of unusual points that can be clearly defined and repeatedly located on compared images. The consistent ability to be replicated is essential not only for the courtroom presentations but for scientific purposes of the method. [2]

All of the faces (11) from the first set (Fig. 4) were photographed from the same distance, and all of them have straight expressions. As well as in the case of the second set, the angles between points were measured, although the statistical calculation may not exhibit the interesting changes between different faces as in the second set of faces.

The pictures from the second set (Fig. 5) were also taken from the same distance, but the expression of the same face varied. The total amount of ten faces was measured.
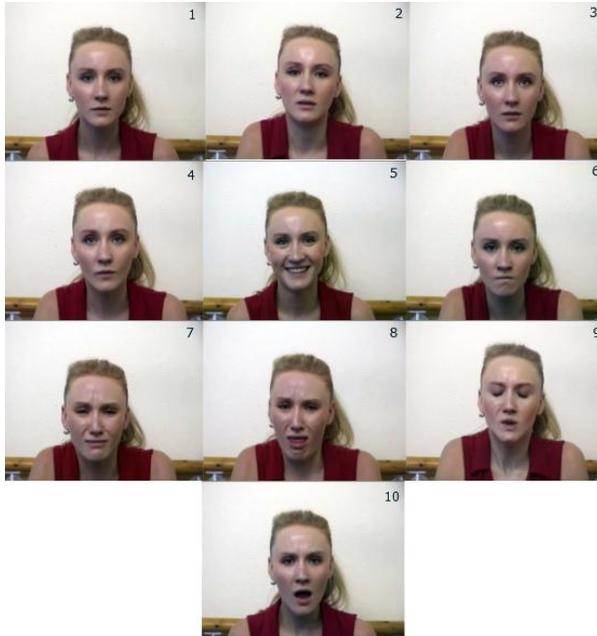


**Figure 5** – Selected 10 faces for the second set

### 2.3. Principle of two faces' comparison

For the experimental comparison of face the expert uses the referential album of model photographs of one person. As our project was focused on manual measurement of the face, our referential album contains, in comparison to 700 images from the research made in [1], reduced number of images. To get the relative coefficient $K_F$, following three simple equations are available:

$$K_n = \frac{l_1}{l_2} \qquad (1)$$

$$K_{ij} = \frac{K_{F1}}{K_{F2}} \qquad (2)$$

$$\lambda = \frac{K_n}{K_{ij}} \qquad (3)$$

where:
$l_1$     - distance between anthropometrical points $i$ and $j$ in the first image,
$l_2$     - distance between anthropometrical points $i$ and $j$ in the second image,
$K_{F1}$   - change coefficient of abscissa between point $I$ and $j$ for the first image set from the table,
$K_{F2}$   - coefficient for the second image,
$\lambda$      - relative value.

The method can be utilized for the images with format at least 18 x 24 cm. The face with the same space orientation as the examined image is searched in referential album. The $\lambda_{ij}$ is calculated for each abscissa. Based on experience, if the difference of minimal and maximal $\lambda_{ij}$ value is lower than 0.2, then the tested face is identified as identical (that in database). [1]
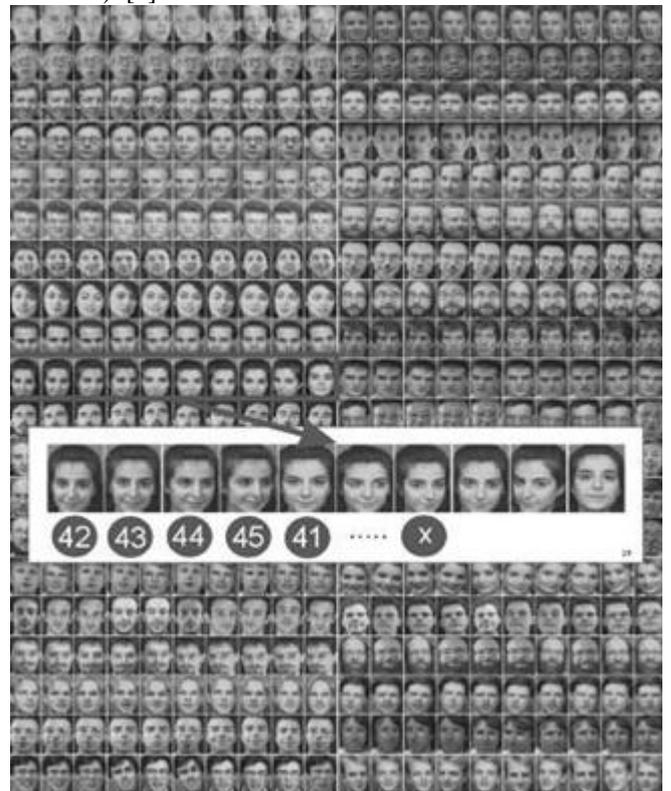


**Figure 6** – Ideological form of graphical album [1]

## 3. RESULTS AND DISCUSSION

Computationally demanding calculations of different and same faces for comparison purposes shows very analogous results to those obtained by the fully computerized method (Tab. 1). Looking to the values of connected points 2-5 and 2-10 we can say the coefficients' results are close. Unfortunately, the values of points 3-7 embody ship rise of nearly 0.4 points, which represent the highest growth in values obtained manually. The slight increase of values can be also observed for the values 3-8 and 3-5. The most

| Abscissae connecting points | Images | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **41** | **42** | **43** | $_11$ | $_12$ | $_13$ | $_14$ | $_21$ | $_22$ | $_23$ | $_24$ |
| **2-5** | 0.963 | 0.969 | 0.973 | 0.964 | 1.143 | 1.024 | 0.900 | 0.963 | 1.027 | 0.967 | 1.045 |
| **2-10** | 1.021 | 1.179 | 1.314 | 1.072 | 1.105 | 1.332 | 0.749 | 0.979 | 1.042 | 0.958 | 1.113 |
| **3-7** | 0.545 | 0.628 | 0.736 | 1.004 | 1.038 | 0.942 | 1.094 | 1.024 | 0.954 | 0.946 | 1.032 |
| **3-8** | 0.878 | 0.887 | 0.900 | 0.988 | 1.141 | 0.845 | 1.288 | 1.035 | 0.923 | 0.938 | 1.077 |
| **3-5** | 0.850 | 0.900 | 0.957 | 0.917 | 1.063 | 1.006 | 1.038 | 0.960 | 0.923 | 0.938 | 1.077 |
| **3-12** | 1.441 | 1.330 | 1.501 | 0.857 | 1.072 | 0.989 | 1.021 | 0.854 | 1.115 | 0.911 | 1.037 |

**Table 1** – Examples of relative coefficients (notes: images 41 – 43 = computerized values of one face; images $_11$ - $_14$ = manually measured values of different faces; images $_21$ – $_24$ = manually measured values of same faces with different expressions)

significant decrease of values appears in the points 3-12. These values are higher for more than 0.2 ratio points. These differences between measured and computerized method may be caused by several reasons:

- images' resolution is different, according to the results of $\lambda ij$ values the resolution of our images is higher, which means better conditions for measurements,
- or the fully computerized method was not too accurate – the edges of points could be in shadow,
- data cannot be directly compared as the faces are various,
- human error may occur despite all the precautions.

| Set 1 - Various Faces | | | | Set 2 - Various Emotions | | | |
|---|---|---|---|---|---|---|---|
| $1^1$ | $1^2$ | $1^3$ | $1^4$ | $2^1$ | $2^2$ | $2^3$ | $2^4$ |
| 0.06 | 0.18 | 0.06 | 0.06 | 0.00 | 0.06 | 0.00 | 0.08 |
| 0.06 | 0.03 | 0.26 | 0.32 | 0.09 | 0.03 | 0.11 | 0.04 |
| 0.07 | 0.03 | 0.06 | 0.09 | 0.02 | 0.05 | 0.06 | 0.03 |
| 0.11 | 0.15 | 0.14 | 0.30 | 0.05 | 0.07 | 0.05 | 0.09 |
| 0.04 | 0.15 | 0.09 | 0.12 | 0.04 | 0.01 | 0.02 | 0.16 |
| 0.05 | 0.22 | 0.13 | 0.16 | 0.00 | 0.26 | 0.05 | 0.18 |

**Table 2** – Examples of absolute values of $\lambda_{ij}$ showing the similarity or variability of faces

Apart from the different values of relative coefficients that can be a bit misleading, the $\lambda_{ij}$ values show exactly the similarity of faces. The faces from the second set have the $\lambda_{ij}$, according to expectation, lower than 0.2. The mean value is 0.06, although in our example one of the value is slightly above the 0.2 value (in the whole set the value occurs only a few times). This can be taken as a result of the expression on the face, which could change the normal proportion of the face. In practical terms, changes like this will occur and brings the requirement for the utilization of additional methods for the face recognition. When exploring the $\lambda_{ij}$ for various faces (first set), the mean value is 0.12, but the value above 0.2 limit emerges multiple times. This clearly shows the difference of each face, which is the intention of the recognition.

Out of curiosity, the angles between selected points were measured and their mean and average deviation was calculated. For the 1st set the calculated deviation median for all values is 2.06°. The maximal deviation between chosen points is 175.70° and the minimal one is 6.00°. The data agreement is 83.00 %. These results, as may be obvious from the previous results, also show high percentage of diversity between various faces as expected. The calculated deviation median for all values in the 2nd set is 2.45°. The maximal deviation is 25.70°; the minimal one is 5.60°. The graphical comparison of the faces with various expressions shows minimal variances in contrast to the different faces. The data agreement is c. 88.37 %, which means high resemblance of data calculated only statistically.

While using more data (proposed 28 points), the accuracy is higher in case of various emotions, respectively lower in case of various faces, which increases the probability of correct recognition or identification of individual. On the other hand, raising the number of used points may extend the length of processing by computer/device. However, decrease in number of points to 12 basic ones will decrease the probability of correct recognition and increase the percentage of errors during recognition.

## 4. CONCLUSION

The face recognition is one of the most utilizable biometric systems in the world. The state-of-the-art of this kind of recognition is very accurate as the modern algorithms evolve almost daily. The biggest resemblance rate is achieved by the forensic applications. Commercial systems' accuracy is not as

high as the forensic one, but the security level is sufficient for these purposes.

This project deals with the comparison of different faces by an older analytical-statistical approach. It is very special how the data act during testing. The method proves its sufficiency when analysing single faces of one person with different expressions, or different faces. However, the method itself is not effective for bigger database of faces. The combination of methods is necessary and desirable for higher accuracy and reliability of the whole performance of the system as we should not rely only on the statistically evaluated data. However, the analytical-statistical method can still be a method suitable for recognition with slight modifications, and with the simultaneous use of other modern algorithms.

## 5. ACKNOWLEDGEMENTS

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